2.0 EXRAD Measurement Concept and Instrument Description

2.1 Rationale and Measurement Concept

As mentioned earlier, EDOP does not have scanning capability and therefore can only measure the vertical and along-track winds (u, w, where u is the along-track wind and w is based on the assumption of a hydrometeor fallspeed estimate) and not the full horizontal wind component. It is highly desirable to have the full wind vector (u, v, w). The EXRAD system development began in 2004 and it was designed for the Global Hawk and ER-2 with capabilities of EDOP, plus a second conical/cross-track scanning beam that provides estimates of 3D reflectivity, surface winds through well-proven airborne and spaceborne scatterometry techniques (Masuko et al. 1986; Carswell et al. 1994, Naderi et al. 1991), and in-cloud horizontal winds through conical scan (VAD) and pseudo dual-Doppler approaches. The completion of this instrument was internally funded at a low level at GSFC over the past few years. One of the primary goals for this effort was to develop a radar system that delivers high science output but will be low-cost relative to typical airborne radars. This two-antenna radar concept is shown conceptually in Figure 6 and Table 2 indicates the parameters that can be measured by this new radar.

While EDOP provided spectacular data from thunderstorms and tropical storms, the full horizontal wind that is critical for understanding key processes of convective transport were unavailable. With conical scanning, ongoing studies with the NOAA P3-based instrument called IWRAP (Esteban et al, 2005) has demonstrated wind retrievals using a 4-beam C- and Ku-band conical scan radar in hurricanes. The atmospheric winds have mainly been derived as mean wind products over the full scan circle, but numerical analyses have performed that allow for pixel-based wind analyses. There are forward and aft views of the same precipitation region at many different azimuth angles in 3D grid cells (pixels). This would provide retrieved horizontal winds over most of the scanned region but with lower accuracies at nadir and near the edges of the swath.

The scanning capability of EXRAD will provide significantly more information than the current EDOP. With conical scanning of the radar over an ocean surface in the absence of precipitation, the surface return over a single 360^o sweep over ~23 km-diameter region (at 35^o incidence angle) provides information on the surface wind speed and direction within the scan circle (Fig. 6) both using one sweep of the radar and also pixel-based analysis. Figure 7 shows the ocean surface radar cross section measured using a 10 GHz airborne scatterometer versus azimuth scan position reported by Masuko et al. (1986). By processing successive scans, the surface winds on smaller scales within the scan circle can be estimated (Long 2002). In precipitation regions, the conical scan provides the 3D structure of reflectivity beneath the plane and the horizontal winds can be estimated on a 1-2 km scale using a pixel-based retrieval under development. In addition to the conical scan, the antenna is capable of cross-track scan that may be useful for coordinating with a cross-track radiometer that may be on the ER-2 payload.

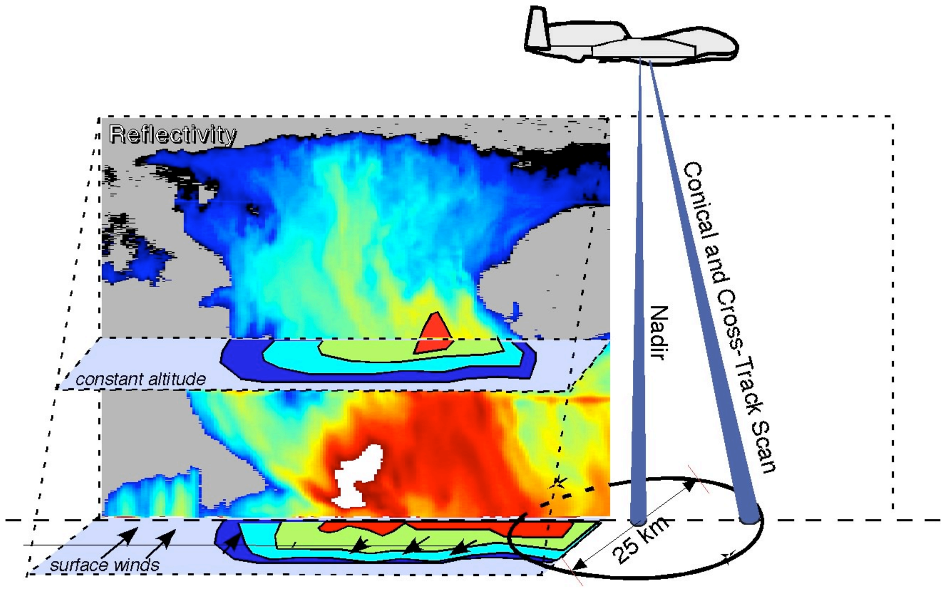

Figure 6. EXRAD measurement concept

Table 2. Parameters derive from nadir and conical scanning antenna.

Parameter	**Nadir**	**Conical Scanning**
Reflectivity	Yes	Yes
Doppler	Yes	Yes
Ocean surface wind speed, direction	No	Yes
Horizontal wind in precip/cloud regions	No	Yes
3D reflectivity struct.	No	Yes

The EXRAD X-band frequency is desirable for airborne weather radars since high power transmitters and off-the-shelf components are readily available and thus costs are relatively low in comparison with higher frequency radars. Furthermore, experience with EDOP has shown that the attenuation problem in heavy rain is tolerable with a nadir-viewing geometry, and its sensitivity at nadir is quite good (-15 dBZ at 10 km altitude for EDOP). Experience has also shown that the Doppler measurements are easier to utilize at X-band versus higher frequencies since the Nyquist velocity (range of unambiguous Doppler measurements) scale inversely with frequency so a Ka-band radar has a Nyquist interval of 1/3rd of an X-band radar.

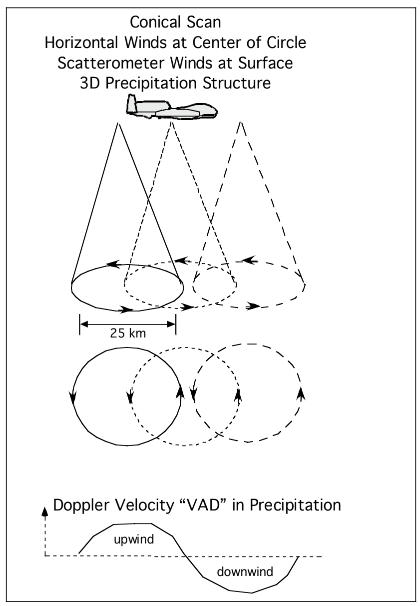

Figure 7. Conical scanning-derived winds.

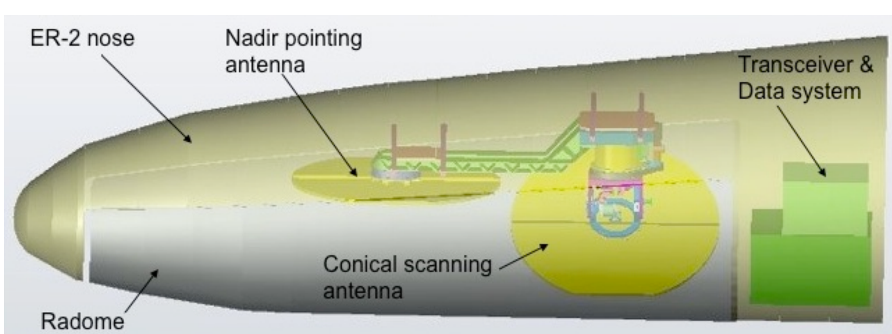

Figure 10. Configuration of EXRAD in the ER-2 nose

Table 3. EXRAD Radar Specifications

Transmitter	TWT
Peak Power (kW)	9.0
RF Freq. (GHz)	9.6 (Scanning) 9.4 (Nadir)
IF Freq. (MHz)	60
PRF (kHz)	5k/4k
Pulse Width (ns)	250-2000
Doppler Range (m/s)	+/- 150
Unambigous Range (km)	30
Maximum Range Resolution (m)	37.5
Maximum Num of Range bins	720
Dynamic Range (dB)	>90
Averaging Time (s)	1/60 (scanning) 0.5 (nadir)
Sensitivity (dBZ) @10 km	-8 (scaning) -15 (nadir)
Scanning Rate (rpm)	10
Power Consumption (W)	400
Overall Weight (lbs)	150
Antenna size (inches)	up to 30” flat plate